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REVIEW

Emerging role of novel biomarkers in the diagnosis of inflammatory bowel disease

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Abstract

There is currently no gold standard test for the diagnosis of inflammatory bowel disease (IBD). Physicians must rely on a number of diagnostic tools including clinical and endoscopic evaluation as well as histologic, serologic and radiologic assessment. The real difficulty for physicians in both primary and secondary care is differentiating between patients suffering from functional symptoms and those with true underlying IBD. Alongside this, there is always concern regarding the possibility of a missed, or delayed diagnosis of ulcerative colitis (UC) or Crohn's disease. Even once the diagnosis of IBD has been made, there is often uncertainty in distinguishing between cases of UC or Crohn's. As a consequence, in cases of incorrect diagnosis, optimal treatment and management may be adversely affected. Endoscopic evaluation can be uncomfortable and inconvenient for patients. It carries significant risks including perforation and in terms of monetary cost, is expensive. The use of biomarkers to help in the diagnosis and differentiation of IBD has been increasing over time. However, there is not yet one biomarker, which is sensitive of specific enough to be used alone in diagnosing IBD. Current serum testing includes C-reactive protein and erythrocyte sedimentation rate, which are cheap, reliable but non-specific and thus not ideal. Stool based testing such as faecal calprotectin is a much more specific tool and is currently in widespread clinical use. Non-invasive sampling is of the greatest clinical value and with the recent advances in metabolomics, genetics and proteomics, there are now more tools available to develop sensitive and specific biomarkers to diagnose and differentiate between IBD. Many of these new advances are only in early stages of development but show great promise for future clinical use.

Key words: Biomarkers; Inflammatory bowel disease; Ulcerative colitis; Crohn's disease; Indeterminate colitis

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Core tip: There is no gold standard test in the diagnosis of inflammatory bowel disease (IBD). Physicians must take into account clinical, endoscopic, and radiologic

as well as serologic and histologic evidence in order to correctly diagnose their patients. Endoscopic evaluation is not only expensive, but is uncomfortable for patients and not without significant risk such as perforation. The use of biomarkers to help in the diagnosis and sub classification of IBD is an expanding area. In this review we touch on those non-invasive markers currently in clinical use before focusing on those more novel tests, with the potential to be highly useful in both diagnosis and differentiation of IBD.

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INTRODUCTION

The European evidence-based Consensus on the diagnosis and management of inflammatory bowel disease (IBD) states that diagnosis should rely on physicians taking into account a number of factors including clinical and endoscopic evaluation as well as histologic, serologic and radiologic assessment[1,2]. There is no gold standard diagnostic tool.

Abdominal pain with, or without a change in bowel habit is a common presenting symptom in primary care. A majority of these patients will be suffering from functional bowel disorders including functional dyspepsia and irritable bowel syndrome. Indeed, functional bowel disorders make up a significant proportion of referrals to gastroenterology outpatient clinics (up to 60%)[3].

The dilemma for physicians is distinguishing a patient with functional symptoms from one with an underlying diagnosis of IBD. Up to 50% of patients with a functional diagnosis are referred on for unnecessary endoscopic evaluation[3].

Conversely, there is also often a delay in diagnosis of cases of true Crohn's disease (CD) and ulcerative colitis (UC), (*i.e.,* time from onset of symptoms to diagnosis). This delay is more marked in the case of ileal CD[4].

Even once a diagnosis of IBD is made, there can still be uncertainty with regard to sub classification into either CD or UC. This is essential, as optimal treatment and management of both conditions is different.

Making this differential diagnosis between CD and UC can be difficult and around 10% of patients are labelled as having an indeterminate colitis (IC)[5].

It is thus clear that even with current available diagnostic tools, as physicians, we still struggle to make accurate diagnoses.

Any investigative test must be acceptable in terms of both cost and comfort to patients. Endoscopic evaluation is not only often uncomfortable as well as expensive, but can be related to significant risk, such as perforation. One recent French study found a rate of between 4.5 and 9.7 cases of perforation per 10000 patients[6].

Radiologic imaging, perhaps most useful in the investigation of small bowel pathology, also has its drawbacks with regard to inter and intra-observer variability, and obviously does not allow for histological sampling[7].

The use of biomarkers to aid the diagnosis of IBD is an ever-expanding investigative area.

A biomarker has been defined as "a characteristic that is objectively measured and evaluated as an indicator of normal biological processes, pathogenic processes, or pharmacologic responses to a [n]...intervention". Example: Cholesterol level[8].

As of yet, there is no one biomarker, which is sensitive or specific enough to make a confident diagnosis of IBD on its result alone. Many are indicative of systemic inflammation and so have limitations in their use.

This review will touch on those already well established in their use before focusing on more recent advances in the development of novel biomarkers for both the diagnosis and monitoring of IBD.

SCOPE OF THIS REVIEW

This review will focus on more recent advances in the development of novel biomarkers for both the diagnosis and monitoring of IBD.

A large number of biomarkers have been reported in the literature.

We have chosen to consider non-invasively obtained biomarkers, as those that are more acceptable to patients, and thus, most promising with regards to clinical utility.

LITERATURE SEARCH

This review of the English language literature on novel biomarkers in the diagnosis of IBD is based on papers contained within the PubMed database. Individual searches of the PubMed database were performed with the boolean operator AND, using the terms: "biomarker", "inflammatory bowel disease", "Crohn's disease", and "ulcerative colitis".

The abstracts were screened for eligibility and all relevant publications were requested as full-text articles. References used in requested papers were then checked for any further studies of potential interest.

BIOMARKERS IN WIDESPREAD USE

Blood based

C-reactive protein: C-reactive protein (CRP) is produced by hepatocytes in response to inflammation, stimulated by certain cytokines. In the case of active

IBD, these cytokines include tumour necrosis factor-alpha (TNF-α), interleukin (IL)-6 and IL-1β[9].

During active IBD, CRP may rise significantly. However, it is not specific and can go up in a variety of conditions including infection, autoimmune conditions, other inflammatory conditions, and malignancy as well as cell necrosis[10].

Elevations in CRP may vary from person to person depending on the individual's immune response; however, it has been shown that rises in CRP are more common in CD rather than UC. The reason for this is unclear, but may have to do with the deeper, more penetrating inflammation in CD compared with the superficial mucosal inflammation seen in UC. It has also been suggested that disease location, independent of severity may affect the level of rise in CRP[11].

In patients with known IBD, rises in CRP have been shown to correlate with active disease on colonoscopy and severe inflammation on histology, hence can be useful in distinguishing active from quiescent IBD[12].

Erythrocyte sedimentation rate: The erythrocyte sedimentation rate (ESR), like CRP is a measure of systemic inflammation and not entirely specific to IBD.

The test measures the distance that erythrocytes have fallen in 1 h in a vertical column of non-coagulated blood[13]. In comparison to CRP, ESR levels peak later and decrease at a slower rate. In view of this, ESR is better at monitoring disease activity/response to treatment after the first 24 h of onset whilst CRP may be more useful in the first 24 h.

ESR is still very commonly used in monitoring of IBD, despite it usefulness being quite limited. It is influenced by a number of factors including age, gender, anaemia, blood dyscrasias and pregnancy[14].

Yoon *et al*[15] found that with regard to correlation with endoscopic activity, both CRP and ESR levels correlated only modestly and that the low sensitivities for detecting endoscopic remission suggest that CRP or ESR alone is not sufficient to reflect endoscopic severity accurately.

Another, more recent meta-analysis found that no level of ESR was predictive of IBD. The highest predictive probability of IBD was reported as 1.6% at an ESR level of 200 mm/h[16].

Antineutrophil cytoplasmic antibodies: Antineutrophil cytoplasmic antibodies (ANCAs) are antibodies against granules of neutrophil cytoplasm. They are detected using indirect immunofluorescence (IIF) and show three main staining patterns: The cytoplasmic (cANCA), the speckled (sANCA) and the perinuclear (pANCA). Perinuclear ANCA (pANCA) has been shown to increase significantly in UC[17].

Joossens *et al*[18] found in their prospective follow-up study that 64% of UC patients were positive for pANCA [and anti-*Saccharomyces cerevisiae* antibody (ASCA) negative]. A further study calculated the rate of pANCA to be 55% in UC and 32% in healthy controls[19].

In UC, the presence of atypical pANCAs has been associated with resistance to treatment of left-sided disease and early surgery. This suggests a role in using the presence of pANCA to identify those UC patients who may require earlier intervention with immunomodulators[20].

ASCA: ASCA are antibodies for mannan in the cell wall of *Saccharomyces cerevisiae* (*S. cerevisiae*)[21].

In comparison to pANCA, which is found in higher titres in UC, high ASCA levels are more specific for CD. Using the combination test ASCA+/pANCA-, one meta-analysis of 60 studies looking at 7860 IBD patients and 3748 controls demonstrated the ability to differentiate adults with CD from those with UC with 55% sensitivity and 93% specificity[22]. Levels have also been associated with phenotypes corresponding to ileal disease, young age at onset, stricturing, as well as penetrating behavior and multiple bowel surgery[23].

Despite high specificity levels, the low sensitivity of ASCA/pANCA testing has prevented its routine clinical use in distinguishing between CD and UC.

Stool based

Faecal calprotectin: Calprotectin is a zinc and calcium binding protein belonging to the S100 family that is derived mostly from neutrophils and monocytes, and has also been detected in activated macrophages[24].

Calprotectin is found in serum, saliva, cerebrospinal fluid, urine and faeces[25]. It is an extremely stable protein, and can be found unaltered in stool samples left unprepared for longer than 7 d.

When the inflammatory process is triggered calprotectin is released due to degranulation of neutrophils, making it very specific for gastrointestinal inflammation[26].

Many studies in the literature have focused on faecal calprotectin (FCP) in terms of accuracy in diagnosis and monitoring of IBD. It has now become a widely used test since it was first described in 1980[27]. One meta-analysis calculated sensitivity and specificity of FCP of up to 95% and 91% respectively. In addition they showed that FCP outperformed other serological markers including CRP and ESR[28].

The National Institute for Health and Care Excellence (NICE) recommends the use of FCP as a diagnostic tool to help in the differential diagnosis of IBD and irritable bowel syndrome (IBS)[29]. When used in this way in both primary and secondary care, it may help reduce the number of referrals for unnecessary endoscopic evaluation. One meta-analysis of 13 studies concluded that FCP testing would result in a 67% reduction in the number of adults requiring endoscopy, but with a delayed diagnosis in 8% of adults because of false negative results[30]. One area of controversy surrounding FCP testing is the determination of an

appropriate cut-off value, above which the result is deemed as positive. In most centres, a relatively low level of 50 μg/g is used.

Pavlidis *et al*[31] looked at this issue in a cohort of adult patients undergoing faecal calprotectin testing in primary care. At a cut off of 50 μg/g, FCP testing had a negative predictive value (NPV) of 98% and positive predictive value (PPV) of 28%. Increasing the cut off value to 150 μg/g gave a very comparable negative NPV of 97%, but a much higher PPV of 71%.

Given these values, it was calculated that by increasing the cut off value to 150 μg/g, this would reduce colonoscopy and flexible sigmoidoscopy bookings by 10% at the cost of 4 missed cases of IBD (*n* = 686)[31].

Faecal lactoferrin: Lactoferrin is an iron-binding protein; it covers most mucosal surfaces. It is found within neutrophil granulocytes and becomes activated in acute inflammation[32]. Similar to faecal calprotectin, it is stable for up to 5 d in faeces. Levels of faecal lactoferrin increase significantly as neutrophils infiltrate the gastrointestinal tract[33]. Levels of faecal lactoferrin have been found to be significantly higher in active IBD than in inactive IBD, IBS and infectious bowel disease. One study reported the sensitivity and specificity of fecal lactoferrin as 92% and 88%, respectively, for UC, and 92% and 80%, respectively, for CD[34].

Sidhu *et al*[35] looked at the relationship between faecal lactoferrin levels in small bowel Crohn's in patients undergoing capsule endoscopy. They found positive predictive and negative predictive values of 100% and 83% respectively for faecal lactoferrin in the diagnosis of small bowel CD detected by capsule endoscopy.

Much like faecal calprotectin, faecal lactoferrin is a sensitive and specific marker in measuring IBD activity. It can help in discriminating between inflammatory and non-IBD as well allowing for the exclusion of IBS in the case of elevated levels.

Previously studied faecal biomarkers: Other faecal markers implemented in the diagnosis, assessment of severity and monitoring of response to therapy in IBD include neopterin and polymorphonuclear neutrophil (PMN)-elastase. Nancey *et al*[36] found faecal neopterin to correlate better with endoscopic activity compared with CRP. The authors also found neopterin to be as accurate as faecal calprotectin in the prediction and monitoring of severity of mucosal damage in IBD.

PMN-elastase has been shown to be able to differentiate active IBD from inactive IBD as well as from IBS, with a diagnostic accuracy of 74.1%, higher than that of CRP (64%)[37].

S100A12 is part of the calcium binding protein family (similar to FCP) and is a stimulator of pro-inflammatory mediators. It is also stable in room temperature for up to 7 d[38].

S100A12 has been shown to have sensitivity and specificity levels of up to 86% and 96% respectively, higher than FCP. It has also been shown to correlate better with intestinal inflammation in comparison to other biomarkers[39] as well as having the potential to be used in monitoring response to therapy[38].

However, despite its promise, S100A12 is not used routinely in practice, as more studies need to confirm its use in IBD evaluation.

Emerging novel blood based markers

Anti-outer membrane protein C: Anti-outer membrane protein C (anti-OmpC) is an antibody directed against the outer membrane porin C transport protein of *Escherichia coli*. Anti-OmpC has been reported in 55% of CD patients[40], whilst in UC and healthy controls, rates were insignificant.

It has been suggested that Anti-OmpC may be of value to aid diagnosis of ASCA negative CD patients. In those patients who are ASCA negative, the prevalence of anti-OmpC has been reported as 5%-15%[41].

Antibodies to flagellin: Identification of commensal bacterial proteins in colitic mice has found the dominant antigens to be flagellins. A strong immune response was seen in one particular flagellin, anti-CBir1. Percent of 50 patients with CD were found to have IgG reactivity to CBir1 in comparison to 6% of UC patients and 8% of healthy controls[42].

In atypical pANCA positive CD patients, 40%-44% have been found to be positive for anti-CBir1 in comparison to only 4% of atypical pANCA positive UC patients.

Thus, the detection of anti-CBir1 may help in the differentiation between atypical pANCA positive CD and UC patients, independently of ASCA[43].

In addition, anti-CBir1 antibody has been found to be associated with ileal involvement in CD patients independent of other serologic markers and has been suggested to predispose to stenosing and penetrating disease in CD[42].

More recently, Schoepfer *et al*[44] demonstrated reactivity towards two new anti-flagellins, anti-A4-Fla2 and anti-Fla-X in 59% and 57% of CD patients as compared to only 6% of UC patients, suggesting a possible role in distinguishing CD from UC.

Anti-I2 antibody: A fragment of bacterial DNA (I2), has been identified from lamina propria mononuclear cells in active CD and shown to be associated with *Pseudomonas fluorescens*[45].

Anti-I2 positivity has been reported as 30%-50% in CD, 2%-10% in UC, 36%-42% in indeterminate colitis and 4%-8% of healthy controls. Anti-I2 has also been found in patients with other inflammatory enteritis (19%)[40,46].

Anti-carbohydrate antibodies: Patients with CD have been found to express antibodies to cell wall carbohydrate epitopes found in different pathogenic

bacteria and fungi. These anti-glycan antibodies include anti-laminaribioside carbohydrate antibody (ALCA) (18%-38%), anti-chitobioside carbohydrate antibody (ACCA) (21%-36%), and anti- mannobioside carbohydrate antibody (AMCA) (28%). ALCA, ACCA and AMCA have been found in 18%-38%, 21%-36% and 28% of CD patients respectively[45-47].

Ferrante *et al*[48] found that patients with CD who were positive for at least one of ALCA, ACCA or gASCA (similar to ASCA) could be differentiated from UC patients with a 77% sensitivity and > 90% specificity. In the differentiation of CD patients from healthy controls however, the specificity fell to 70.3%.

Overall, the sensitivity of these anti-glycan antibodies has been found to be low by a number of studies, which is a limiting factor in their clinical use[48-53].

Pancreatic antibodies: Antigen-specific pancreatic antibodies (PABs) against exocrine pancreas have been found to be present in 20%-30% of patients with CD, but in less than 2%-9% of patients with UC, and can be found in very few patients with non-IBD related conditions[54,55].

The major zymogen glycoprotein 2 (MZGP2) has recently been identified as the primary autoantigen of PAB[56] and has prompted the development of techniques to allow for its identification in routine practice.

A study from Pavlidis *et al*[57] in 2014 assessed the clinical relevance of PABs by way of a novel ELISA technique in the largest IBD cohort tested in this way to date. They were able to confirm the high specificity of anti-MZGP2 antibodies for CD and their association with disease severity phenotypes. IgA anti-MZGP2 antibodies were more prevalent in CD patients with early disease onset (P = 0.011). In addition, anti-MZGP2 positive patients more frequently had extensive disease with ileal involvement. Patients with longer disease duration were more likely to have IgG anti-MZGP2 antibodies[57].

Alpha-1 antitrypsin and granulocyte colony-stimulating factor: Soendergaard *et al*[58] looked at serum samples from 65 patients with UC with varying disease activity and from 40 healthy controls. They measured levels of both alpha -1 antitrypsin (AAT) and granulocyte colony-stimulating factor (G-CSF).

AAT levels were able to differentiate between mild, moderate and severe UC, performing better than CRP.

In addition, the authors found that combination measurement of AAT and G-CSF in patients with diagnosed UC held enough statistical power to differentiate between patients with mild, moderate, and severe disease activity.

Genetics

In the recent past, a number of genome wide association studies (GWAS) have discovered a number of susceptibility loci in the investigation of UC and CD-specific genomic profiles.

Ellinghaus *et al*[59] found that variants in two genes, PRDM1 and NDP52 determined susceptibility to CD. PRDM1 was found adjacent to a CD interval identified in GWAS and encodes a transcription factor expressed by T and B cells. *NDP52* encodes a protein functioning in autophagy of intracellular bacteria and signaling molecules, supporting the role of autophagy in the pathogenesis of CD.

The IBD chip European project looked at a number of CD-single nucleotide polymorphisms to determine their influence on clinical course and phenotype of the disease. The *NOD2* gene was found to be the most important genetic factor, being an independent predictive factor for ileal location, stenosing and penetrating CD. It was also associated with a more complicated disease course and the need for surgery[60].

A further recent meta-analysis of CD and UC GWAS reported on significant findings from more than 75000 cases and controls. The authors identified 71 new associations increasing the total number of confirmed IBD susceptibility loci up to 163. They found that most loci contributed to both phenotypes. Interestingly, there was also considerable overlap between susceptibility loci for IBD and mycobacterial infection, suggesting pathways shared between host responses to mycobacteria and those predisposing to IBD[61].

Traditionally, CD has been associated with a Th1 cytokine profile, and UC with Th2 cytokines. However this concept has been since challenged by the discovery of Th17 cells and Treg cells. GWAS indicate that IL23R and five additional genes involved in Th17 differentiation (IL12B, JAK2, STAT3, CCR6 and TNFSF15) are associated with susceptibility to CD and partly also to UC[62].

In terms of the clinical application of genetics in the diagnosis of IBD, some focus has been made on identifying genetic markers from colonic tissue retrieved from endoscopic biopsy. von Stein *et al*[63] identified seven genes as differentially expressed in IBD, making it possible to discriminate between patients suffering from UC, CD, or IBS (P < 0.0001) using the clinical diagnosis as gold standard.

Much more recently, following on from this work, this same genetic panel was tested on biopsy material from 78 patients with a complicated course (38 probably UC, 18 CD, 22 IBDU). Testing led to a change of the primary diagnosis in a significant number of patients with the initial diagnosis of UC and CD and suggested a clinically probable diagnosis in most of the patients with IBDU and in those with an acute flare of colitis[64].

Epigenetics

Epigenetics describes gene-environment interactions affecting gene expression but with no changes in the

DNA sequence.

Micro-RNAs (miRs) are single-stranded noncoding RNAs, around 22 nucleotides in length that remain highly conserved throughout evolution[65]. Since they were first described in the 1990s, over 1600 miRs have been described in humans. miRs are transcribed by RNA polymerase into pre-miR, which is then processed in the nucleus and then cytoplasm. miRs regulate gene expression and thus a number of biological processes such as cell proliferation, differentiation and death. Changes in miR expression have been associated with a number of diseases including IBD[66].

Studies have looked at miR profiles in peripheral blood samples from patients with IBD *vs* controls and in CD patients *vs* UC patients. Several miRs have been found to be either up or down regulated. One paediatric study also found differentially expressed levels of certain miRs between serum samples from children with CD compared with healthy controls[67,68].

A recent paper from Schaefer *et al*[69] found CD was associated with altered expression of 6 miRNAs while UC was associated with 9 miRNAs in whole blood. They also found altered expression of different miRNAs in saliva from both UC and CD patients.

They suggest that there are specific miRNA expression patterns associated with UC *vs* CD, and hence that scrutinizing miRNA expression in saliva and blood samples may be beneficial in monitoring or diagnosing disease in IBD patients.

Metabolomics

Metabolomics refers to the study of the many small molecule metabolites present in biological samples, in order to determine the underlying fingerprint of specific cellular processes.

The current main technologies used for metabolomics include ^{1}H NMR spectroscopy, gas chromatography spectrometry (GC-MS) and liquid chromatography-mass spectrometry (LC-MS). These techniques have the advantage of being extremely sensitive and of allowing experiments to be performed in a cost-effective high-throughput manner[70,71].

^{1}H NMR spectroscopy has so far been most widely used in studies on different biofluids from IBD patients. A number of studies have reported differences in metabolic profiles between IBD patients and healthy controls as well as between CD and UC[72,73].

These studies described have mainly focused on the detection of amino acids, TCA cycle intermediates, and on metabolites involved in fatty acid and purine metabolism.

Metabolites of gut bacteria have been detected in urine[74]. Any change in the gut microbiome, which has been shown to be important in the pathogenesis of IBD, may alter the urinary metabolic profile. Thus, urinary metabolites are an attractive option as potential biomarkers for IBD[75].

A study by Williams *et al*[76] looked at the urinary metabolic profiles of CD and UC patients using ^{1}H NMR spectroscopy. They found significant decreases in the levels of hippurate (a metabolite derived from microbiota) in IBD patients.

Other studies have also demonstrated low levels of hippurate in IBD patients using ^{1}H NMR spectroscopy and in addition, have been able to separate between IBD patients and healthy controls[72,77].

Studies have shown that metabolic profiling of serum and plasma by way of ^{1}H NMR spectroscopy is able to discriminate between UC and CD although less reliably than discrimination between UC/CD and healthy controls[72,73].

Further studies have found that profiling of amino acid and TCA cycle-related metabolites can distinguish reliably between UC and CD[78] and also that correlation of metabolic profiles of amino acids with disease activity, suggesting a role in monitoring of IBD[79].

The metabolic profiling of faecal extracts in IBD has shown significantly decreased levels of short chain fatty acids in comparison to healthy controls[80].

Profiling of the gut microbiota as well as the metabolites from faecal extracts may also give further indications to disturbances of gut bacteria in IBD and hence pathogenesis of the disease[81].

Another advance in the field of metabolomics and IBD is the use of breath testing as a potential biomarker.

A recent review by Kurada *et al*[82] found only 12 (small) studies in the literature, which evaluated the breath metabolome for diagnosis of IBD. In the case of diagnosis and differentiation of IBD, the volatile organic compounds (VOCs) measured in these studies included mainly pentane, ethane, propane, butane or nitric oxide (NO).

Dryahina *et al*[83] demonstrated elevated levels of pentane in IBD (CD > UC) compared to healthy controls, as did Pelli *et al*[84].

In addition, Pelli *et al*[84] also showed an association between both ethane and propane levels and IBD ($P \leqslant 0.001$ for both).

Exhaled NO has been shown to be higher in UC patients compared with CD[85].

With regard to disease activity, one study found a direct correlation between breath pentane levels and WBC scan uptake[86]. Ethane levels have also been shown to correlate with endoscopic activity of disease[87].

Although there have been some promising results from studies, breath analysis is not yet ready for clinical use. Further work is needed to determine the exact breath metabolome patterns in IBD.

Proteomics

Proteomics is a more recently advancing area in the identification of new biomarkers. It is based on the analysis of protein expression in healthy and diseased tissues and to carry out protein profiling.

Meuwis *et al*[88] looked at the sera of 120 patients (30 CD, 30 UC, 30 inflammatory controls and 30 healthy controls). They identified 4 proteins of acute phase inflammation (PF4, MRP8, FIBA and Hpα2).

A much more recent study looked at circulating protein biomarkers in the interleukin-10 knockout [IL-10(-/-)] mouse, a model that develops a time-dependent IBD-like disorder that predominates in the colon[89]. They identified a total of 15 different proteins to be differentially accumulated in serum samples from mid- to late-stage IL-10(-/-) mice compared to early non-inflamed IL-10(-/-) mice, suggesting a role for protein profiling in assessing severity and response to treatment.

CONCLUSION

There is a need for more accurate and cost effective biomarkers in the diagnosis and differentiation of IBD. Development of non-invasive biomarkers is paramount in order to be acceptable to patients and to avoid more invasive assessment, such as endoscopy, which is not without risk.

Current serum testing includes CRP and ESR, which are cheap, reliable but non-specific and thus not ideal. Stool based testing such as faecal calprotectin is a much more specific tool and has now a lot of positive evidence behind it to support its use clinically.

It should be highlighted that as of yet, and despite recent advances, there is no biomarker reliable enough to make a confident diagnosis of IBD without going on, in the case of a positive test, to perform confirmatory colonoscopy. Rather, these non-invasive tests are used currently as an adjuvant to endoscopic evaluation; and to avoid unnecessary procedures where a negative test would indicate no underlying inflammation and no pathology of any cause.

Non-invasive sampling is of the greatest clinical value and with the recent advances in metabolomics, genetics and proteomics, there are now more tools available to develop sensitive and specific biomarkers to diagnose and differentiate between IBD.

This review has touched on the great advances, which have been made in the ever-expanding area of biomarkers in IBD. However, more work is now required to help bring these new techniques into everyday clinical practice.

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